

IMPACT VAPORIZATION: LATE TIME PHENOMENA FROM EXPERIMENTS P.H. Schultz, Dept. of Geological Sciences, Brown University, Providence, RI 02912, D.E. Gault, Murphys Center of Planetology, P.O. Box 833, Murphys, CA 95247.

Previous experiments revealed an increase in impact vaporization for volatile-rich targets (dry-ice) with decreasing impact angle and increasing atmospheric pressure as documented by high frame-rate (35,000 fps) images of the self-luminous ionized vapor cloud. These experiments have continued at the NASA-Ames Vertical Gun Range in order to investigate the following processes: (a) effect of vaporization on late-time ejecta dynamics; (b) atmospheric response revealed by quarter-space experiments with airflow indicators; and (c) the effect of impact vaporization on cratering efficiency, crater aspect ratio, and ejecta emplacement. Aluminum (0.635 cm-diameter) spherical projectiles and lexan cylinders (.31 x .31 cm) impacted into a 1 cm layer of dry-ice powder overlying a granular substrate with velocities from 2.3 to 6.3 km/s.

Ejecta Curtain Evolution: Vertical impacts into dry-ice powder overlying No. 24 sand under near-vacuum conditions (5 mm Hg) produced no observable self-luminous ionized cloud at 35,000 fps (1). Slower framing rates (5800 fps) have revealed, however, a blue vertical spike within the first 0.17 ms of a 5.8 km/s impact that was not previously visible. An ionized blue vapor cloud subsequently rose at 800 m/s while expanding at 300 m/s. This ionized cloud disappeared after 0.34 ms, evolving into a non-luminous expanding cloud preceding the ejecta curtain and scouring the pre-impact surface. The ejecta curtain behind the expanding cloud formed the classical funnel-shaped profile although the curtain angle at early stages was less than 30° . At lower impact velocities (1.8 km/s), a spherically expanding non-luminous cloud rose above the impact. For both events, the early-time expanding cloud had no obvious effect on late-time curtain development, which was indistinguishable from a nominal impact under vacuum conditions.

Under atmospheric conditions (700 mm Hg, Argon), a 5.9 km/s (launch velocity) into dry-ice produced a brilliant self-luminous ejecta cloud that became opaque after 1.6 ms. The rising ionized ball observed at 35,000 fps was invisible due to exposure saturation and slow frame rate. The ejecta curtain was distinctly more distorted (convex-outward) than the curtain for impacts into No. 24 sand without the dry-ice layer. Late-time curtain evolution, as under vacuum conditions, did not reflect the early-time interactions.

Atmospheric Response: A plexiglass sheet adjacent to the projected impact point revealed the interior of the growing ejecta curtain. Flexible black and white yarn spaced 10 cm apart and 5 cm apart on either side of the impact point provided a record of the airshock passage and the airflow behind the advancing ejecta curtain. These experiments used 0.31 x 0.31 cm lexan cylinders impacting pumice with and without dry-ice at about 5.0 km/s (launch velocity) under 395 mm Hg of Argon.

Without dry-ice, passage of the airshock was detected by the tracers and dissipated rapidly prior to the growth of the ejecta curtain. Movement of the airflow tracers revealed the vertical airflow behind the outward-moving ejecta curtain inferred in previous studies (2). Barocells also recorded

the decrease in atmospheric pressure immediately behind the advancing ejecta curtain. With dry-ice powder, a very different response was recorded. A hemispherically expanding "bubble" inside the ejecta curtain expanded at 120 m/s above the crater. The self-luminous projectile wake moving downward, also at 120 m/s, disappeared as it encountered the bubble.

Ejecta Emplacement: Late-time curtain evolution was not modified by early-time impact-vaporization. This observation was further confirmed by the nominal distribution of ejecta for impacts into sand. An impact into dry-ice on pumice under 0.25 P_o produced the previously reported contiguous rampart, which is a response to late-time airflow produced by the advancing ejecta curtain (2).

Cratering Efficiency and Crater Shape: The presence of a near-surface layer of dry-ice did not affect cratering efficiency or the crater aspect ratio under vacuum conditions for vertical impacts into dry-ice. Although cratering efficiency for impacts into pumice was relatively unaffected, the diameter-to-depth ratio increased to 12. The presence of an atmosphere significantly reduces cratering efficiency for impacts into compacted pumice (3), and only by 30% for impacts into No. 24 sand. Impact vaporization, however, raises these values to nominal vacuum conditions. The aspect ratio for impacts into sand and pumice were increased, relative to values without dry-ice. The most significant effect occurred for oblique impact (15°) into sand under vacuum conditions. Efficiency was more than double the value of an impact into sand without dry-ice, and the aspect ratio increases from about 4.3 (without dry-ice) to 5.3 (with dry-ice). These results are consistent with the previous observations from the high frame-rate photographs (35,000 fps) that indicated little vaporization for vertical impacts in a vacuum but increased vaporization for oblique impacts or impacts under atmospheric conditions. To this observation should be added the apparent decoupling between vapor and crater growth under vacuum conditions (the vapor phase rising rapidly above the event).

Concluding Remarks: While simple airflow produced by the outward movement of the ejecta curtain can be scaled to large dimensions (4), the interaction between an impact-vaporized component and the ejecta curtain is more complicated. The goal of these experiments was to examine such interaction in a real system involving crater growth, ejection of material, two-phased mixtures of gas and dust, and strong pressure gradients. The results will be complemented by theoretical studies at laboratory scales in order to separate the various parameters for planetary-scale processes. These experiments prompt, however, the following conclusions that may have relevance at broader scales. First, under near-vacuum or low atmospheric pressures, an expanding vapor cloud scours the surrounding surface in advance of arriving ejecta. Second, the effect of early-time vaporization is relatively unimportant at late-times. Third, the overpressure created within the crater cavity by significant vaporization (oblique impacts, atmospheric conditions) results in increased cratering efficiency and larger aspect ratios.

References: (1) Schultz, P.H. and Gault, D.E. (1985) Lunar and Planetary Science XVI, 740-741, Houston; (2) Schultz, P.H. and Gault, D.E. (1984) Lunar and Planetary Science XV, p. 732-733, Houston; (3) Schultz, P.H. and Gault, D.E. (1983) Lunar and Planetary Science XIII, p. 694-695, Houston; (4) Schultz, P.H. and Gault, D.E. (1981) in Geol. Soc. Amer. Sp. Paper 190, p. 153-174.